

FARM DESIGN FOR WHITE BUTTON MUSHROOM CULTIVATION



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Introduction

Today mushroom cultivation is one of the biggest money spinning agri business enterprises in the world besides being an important horticultural cash crop. Mushroom is valued as a delicacy having tremendous attributes on the basis of food value, is now recommended as a health food rich in proteins by Food and Agricultural Organisation of United Nations for bridging the protein malnutrition gap in combination with soybean in the developing countries of the world. Mushroom as food is important as it is produced from recyclable agro-wastes/agro-byproducts and the requirement of land is not pre-requisite in its cultivation, as it is grown indoors in protected houses seasonally or with environment control, with intensive space utilization in vertical/horizontal axis in the cropping room. Mushroom being an indoor crop does not require arable land, except for some non-agricultural land to build the infrastructure for preparation of substrate, raising of crop, preparation of spawn and postharvest handling. White button mushrooms in India is grown seasonally and in environment controlled cropping houses and both require building of basic infrastructure. Seasonal growing of temperate mushroom is done for 5-6 months when outside temperatures are favourable for the crop raising, i.e., during winter months in N.W. plains of India and from September to April in the hills. The seasonal growing will be termed as low input-low production system and the environment controlled round the year growing system is high input-high production system and both are relevant as far as economics of mushroom cultivation is concerned.

In the 18th century mushrooms were cultivated in open fields and Tournefort (1707) gave a comprehensive description of commercial production of button mushrooms. It was Chambry (1810), a French gardener, who began to cultivate mushrooms in underground quarries in Paris, thus making it possible for year-round production. Callow (1831) showed that mushroom production was possible all the year round in England in rooms specially heated for the purpose. Callow gave details of the design of cropping houses (crediting it to Oldacre, a garden Superintendent in UK) and later successfully grew mushrooms all the year round in such a structure and obtained a yield of 7.3 kg/m² in 24 weeks of cropping, as compared to mushrooms yields of 10 kg/m² obtained in 1950 in UK. It is now accepted fact that protected cropping of mushrooms was pioneered in caves in France, though the earliest mushroom houses were developed in England. Mushroom production then quickly became established in various countries of Europe and soon spread to USA. Large scale white button mushroom production (Flegg *et al.* 1985) is now centered in Europe (mainly W. Europe, with Poland being exception), North American (USA, Canada), Australia, South East Asia (China, Korea, Indonesia, Taiwan) and South Asia (India).

In India, protected cropping of mushroom was started on a modest scale in early sixties at Solan and later it was taken up in cooler regions in other neighbouring states like Jammu and Kashmir, Tamil Nadu and Uttar Pradesh. Earlier button mushrooms were grown in make shift rooms or already built structures with minor modifications made for ventilation, etc. The growing was done either in wooden trays or shelves and compost prepared by long method in a single extended outdoor phase (without steam pasteurization). Soon with availability of know-how and increased interest by research and development workers, mushroom farming took the shape of cottage industry in Jammu & Kashmir, Haryana, Himachal Pradesh and other states. Some large mushroom farms were also built in areas around Solan, more so because of proximity to Mushroom Research Laboratory at Solan for know-how and cooler climate prevalent in the area for growth of white button mushroom (*Agaricus bisporus*). But today mushroom farms are being built at all elevations/places in India with availability of know-how for cultivation in environment controlled cropping houses, specially built for the purpose. More and more modifications and innovations were perfected to suit growing conditions in India and mushroom farm design developed using locally available materials/machinery for higher productivity at lower costs (Dhar, 1995). Following the Dutch pattern of bulk pasteurization in tunnels and growing in beds laid on shelves inside the environment controlled cropping rooms, the mushroom industry received great impetus in the last 15 years in India. More and more modern mushroom growing units/Export Oriented Units have been built by big industrial houses chiefly for export. Most of these EOU's are located in tropical plains of India where saw materials required for its cultivation are easily available.

The importance of a proper and suitable design for a commercial mushroom farm suited to conditions in India has become a necessity and details of the farm design perfected over a period of time with special requirements of growing in tropical areas in India are described in this chapter.

Selection of site and pre-requisites

Before selection of site for building of infrastructure for a mushroom farm is made, it is necessary to look into the following pre-requisites:

- i) Training on mushroom production technology.
- ii) Preparation of a project report.
- iii) Arranging the finance.

Mushroom being an indoor crop, involves heavy expenditure on building of infrastructure, purchase of machinery and equipments, raw materials, labour and energy. It is very important for an entrepreneur to undergo practical

oriented training for learning and understanding various stages of mushroom cultivation. There are scores of institutions in India besides NRCM, where basic training on cultivation of mushroom is imparted. These are the Agricultural Universities located in length and breadth of the country, institutions like NGO's, KVK's and CSIR labs and others. After completion of the training, a detailed project report has to be prepared based on the size of the mushroom farm and type of mushroom to be cultivated. The project report can be prepared by specialists/experts or by Govt. Institutions like NRCM, Solan. Finally the third difficult task will be for arranging the finance for the project. There are scores of financial institutions which finance mushroom projects in the country. Notable amongst these are the nationalized banks, State Government financial institutions, NABARD, foreign banks (with permission from Exim Bank, GOI) and other such organisations.

Subsidy/grants are available from National Horticulture Board, GOI; APEDA, GOI; Ministry of Food Processing, GOI; and others.

For selection of site, the following points have to be taken into consideration for greater operational efficiency and cost effective production of mushrooms at the farm:

- i) The site should be nearer to the residence of the entrepreneur, for effective involvement in supervision and decision making at the farms.
- ii) The site should be serviced by a motorable road, or be nearer to a road head to reduce costs on transportation of raw materials to the farm/ finished product to the market.
- iii) Availability of plenty of water at the site.
- iv) Easy availability of raw materials at competitive rates in the area.
- v) Easy availability of labour at cheaper rates.
- vi) Availability of electricity at competitive rates, as power is a major input in mushroom cultivation.
- vii) Green cover at the site to ensure clean environment in the surrounding.
- viii) The site should be away from industrial pollutants like chemical fumes, coal exhaust and other such pesticide/chemical pollutants that cause harm to mushroom production.
- ix) There should be provision for sewage disposal at the site.
- x) There should be provision for future expansion at the site.

Components of a Mushroom Farm

Farm design deals principally with the location/building of various infrastructural facilities required for different operations like composting,

spawn making, cropping and post harvest handling on a piece of land in such a way that various operations are performed with greater efficiency at the minimum cost. Since mushroom growing is principally an indoor activity, hence construction of infrastructure needs to be done with skill and under expert guidance.

Button Mushroom *Agaricus bisporus* and *A.bitorquis* grow on composts prepared by aerobic fermentation of cereal straws and animal manures, unlike *Pleurotus* and *Volvariella* which grow directly on unfermented cellulosic materials. For commercial production of button mushrooms, the entire process can be divided into four parts viz, (i) Composting (substrate preparation) (ii) Spawn preparation (seed) (iii) Cropping and crop management (crop growth) and (iv) Post harvest handling (packaging/processing). For these operations, the following infrastructure is required to be built :

(A) Composting Unit:

- (a) Outdoor platform for pre-wetting/mixing and Phase-I composting in stacks outdoors/indoor bunkers or aerated chambers for Phase-I indoors.
- (b) Indoor Phase-II in peak heating/bulk pasteurization-chambers.
 - (i) Peak heating chamber
 - (ii) Bulk pasteurization chamber
- (c) Casing pasteurization chamber.
- (d) Air Handling Units for cooling of compost in summer months (special requirement in tropical regions).

(B) Spawn unit:

- (a) Spawn production laboratory.

(C) Cropping unit:

- (a) Seasonal cropping rooms with no environmental control system.
- (b) Environment controlled cropping rooms for round the year cultivation.
- (c) Provision for environment control, air conditioning and forced air circulation installations.

(D) Post harvest handling unit:

- (a) Pre-cooling chamber.
- (b) Canning hall with canning line.
- (c) Packaging room.

The compost for button mushroom cultivation is prepared by traditional long and short methods. Long method of composting is low technology-low output process and will not require building of bulk treatment chamber for composting as is done in short method. Compost by long method is prepared in a single phase with periodic turnings on a covered composting platform. Short method of composting is done in 2 phases, phase-I is the outdoor fermentation in a stack or in an aerated bunker and phase-II in an insulated bulk pasteurization chamber or peak heating chamber where compost is subjected to uniform high temperature treatment for pasteurization (57-59°C) followed by high temperature (aerobic) controlled fermentation at 45-48°C (also called conditioning/enrichment of compost). The bulk chamber is insulated on all sides, ceiling, floors, walls, doors and made leak proof. The growing rooms will also have insulation as above to cut-off the external environment for simulated climate controls to be effective. But for seasonal growing, a normal brick walled cropping room with a brick lined floor and a false ceiling will be good enough to produce a healthy crop of mushrooms in appropriate season on hills or in plains. A simple forced air circulation system is sufficient to provide necessary air changes in the room for removal of CO₂ from seasonal cropping rooms. In case of insulated/climate controlled cropping rooms, the air handling units are installed outside of each cropping room for creating climate inside during cropping. A spawn laboratory and a canning unit will be required on large farms as supporting units for seed/spawn production and canning of the mushrooms produced, respectively.

General Layout/Location of various Units

After selection of the site, the general layout of a mushroom farm is carefully planned keeping in view the proximity of site area to motorable road. Some important factors taken into consideration before selection of site for the farm are availability of clean water, regular availability of power with 3 phase facility, drainage arrangements, availability of raw materials and labour, vicinity of market and green cover in the surrounding area. The site should be away from populated area as foul odours emanating from the compost yard can be bothersome and a source of pollution. A commercial mushroom farm consists of the following units: a) Composting unit comprising of covered outdoor composting yard or an aerated bunker, pasteurization chamber/peak heating room, casing pasteurization chamber b) Spawn unit c) Cropping unit d) Post harvest unit. The composting yard is built nearer to the main road for operational convenience. The bulk chambers are built on the other side of the composting yard (away from road) so that the distant end of the chamber opens nearer to cropping rooms and away from composting yard (Fig.1). The cropping room are built away from composting area for reasons of cleanliness and avoiding contamination by

(i) Covered outdoor composting platform: The composting yard (Fig.2) is required for phase-I of composting viz: pre-wetting/mixing and outdoor aerobic fermentation in a pile. The composting yard should necessarily be a covered shed without side walls where rain will not interfere in the normal process of composting process. The high roof will facilitate escape of foul gases into the atmosphere. The foundation of the composting yard should be laid on a firm ground. After digging, a layer of sand 15-20 cm thick is laid followed by a layer of broken stone/brick pieces 15-20 cm thick. Thereafter, a cemented floor is poured in one operation, 20 cm thick, preferably reinforced cement concrete. The provision for understack aeration is laid in the floor of the composting yard in the form of perforated pipes, connected to air blower. The floor is given a run-off of 1 cm per running meter away from the bulk chamber towards the gummy pit.

The roof of the outdoor composting platform is built on tresses or RCC pillars 20-25 ft. high with GI roofing on top. The sides are without a wall to allow the foul gases to escape into the atmosphere. The sides of the shed are closed under special circumstances when composting is done in hot summer

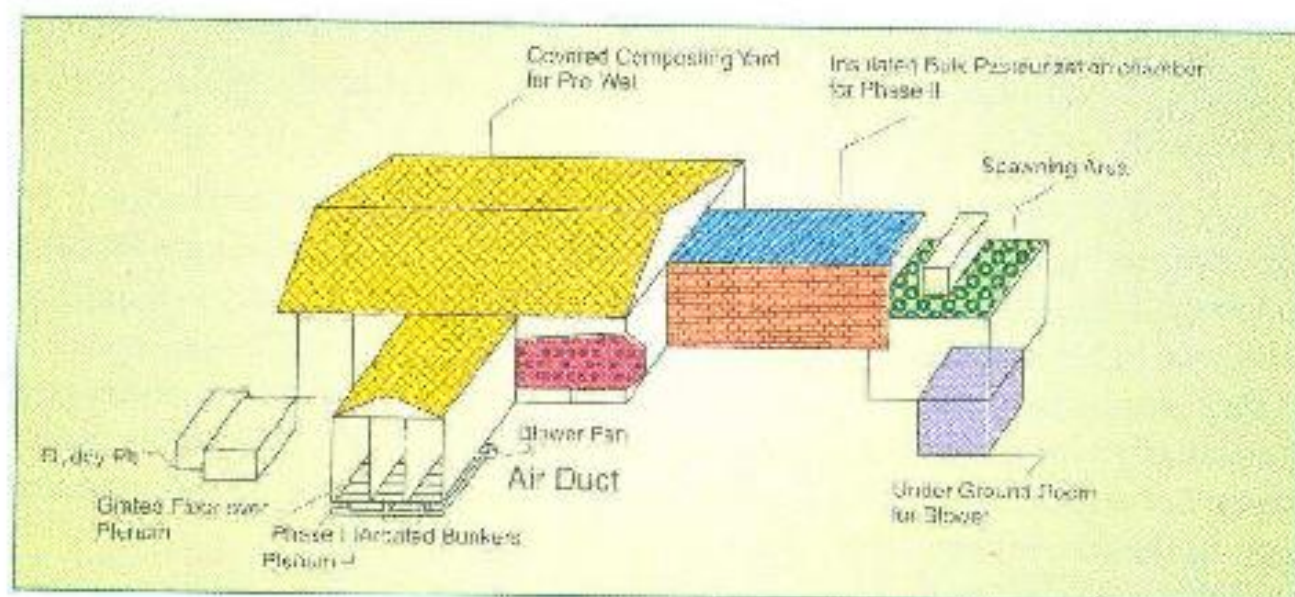


Fig. 2. Composting yard, bulk chamber and spawning area

months in tropical area. The gummy pit is built away from the bulk chamber on one end of the platform. The gummy pit is provided with a dewatering pump and a hose. The covered composting yard should be big enough to hold compost stacks for phase I of composting, and the size of the composting yard will be determined by the number and capacity of bulk chambers. On an average one tonne compost occupies about one meter length of the compost yard, with an extra space of 2-3 m left on each side for turning with machines. Two bulk chambers will require a platform with 10-15 m width. For two bulk chambers of 25 tons compost capacity each, a composting yard of 35 x 15m should be good enough to concurrently run various operations like

prewetting/phase-I at a time for both the chambers. It is, however, advisable to provide understack aeration for outdoor composting on the platform. The compost yard should have a 3 feet wall on periphery to prevent entry of run off water in hilly areas in rainy season, which can bring in nematodes, insect pests, and other undesirable elements into the compost yard. The compost yard should be approachable by a motorable road on one side (away from bulk chamber), so that the raw materials can directly be unloaded on one end of the platform, which will save the labour cost of transporting the raw materials from road head to compost yard. In hilly areas a chute can be built from road head down to the compost yard for depositing the raw materials onto the platform directly from the motorable road, thus reducing the labour costs.

Water connection with 2"-3" dia pipe should be available at the composting yard permanently with additional portable hose pipe of appropriate dia for use during pre-wetting. One dewatering pump with a hose should be installed in the gummy pit to pump out the run-off water for its reuse during pre-wetting.

A drain should run on the two sides of the platform to facilitate periodic cleaning of platform. Alternatively, sunken traps for drains and fresh water connection can be provided at the composting yard.

A few 3-phase 15 Amp power connections should also be provided at the composting yard for operating machines like automatic compost turning machine, filling line and spawning machine. The yard should be well lighted with tube lights and strong search lights to facilitate round the clock operations at the composting yard. An overhead or underground water tank is necessary, particularly where water is scarce, to store water for timely operations. Rain water harvesting system built as part of the farm could be of tremendous help to the mushroom farm, saving costs.

Aerated systems of phase-I are built in the form of aerated bunkers, used for phase-I of composting in place of outdoor composting in stacks/ricks. There are two types of aerated bunkers:

a) Low pressure aerated bunkers: These aerated bunkers are ordinary rooms with single brick walls on longer sides, built over a plenum with slitted/grated top forming the floor of the bunker (Fig 3). The plenum is a closed chamber under the grated floor, about 1 ½ to 2 feet deep with closed ends. The plenum is serviced by a blower fan delivering air into the compost material heaped over the grated floor.

The dimensions of a phase-I bunker for a bulk chamber of 40' x 10' x 13' (h) for 25 tons of compost (final output) should be 45' x 12' x 15' (h), covered with a slanting GI roof over tresses/wooden frame. There is a free

space between the side walls on top and the GI roof for escape of gases during phase-I process. There is no requirement of insulation anywhere in the bunker. The two shorter openings of the chamber are left open, and compost held in position with use of wooden planks sliding into the channel.

The air quantity required to be delivered into the composting materials periodically (5 minutes in every hour round the clock) is 25m^3 air/ton composting material/hour ($1/10^{\text{th}}$ of air quantity normally delivered in phase-II chamber), with return pressure of 50mm water level. This aerated bunker of above dimensions will accommodate about 34-35 tons of pre-wetted/blended composting material, which will finally yield about 25 tons of ready to spawn compost after completion of phase-II of composting. The blower fan is placed on sides/underground blower room/on top of the roof (if roof is made of RCC). The blower fan is fitted with a timer to enable the fan to blow air for 4-5 minutes every hour. Also placed in the plenum air is an oxygen sensor to measure oxygen content of the air below the composting material.

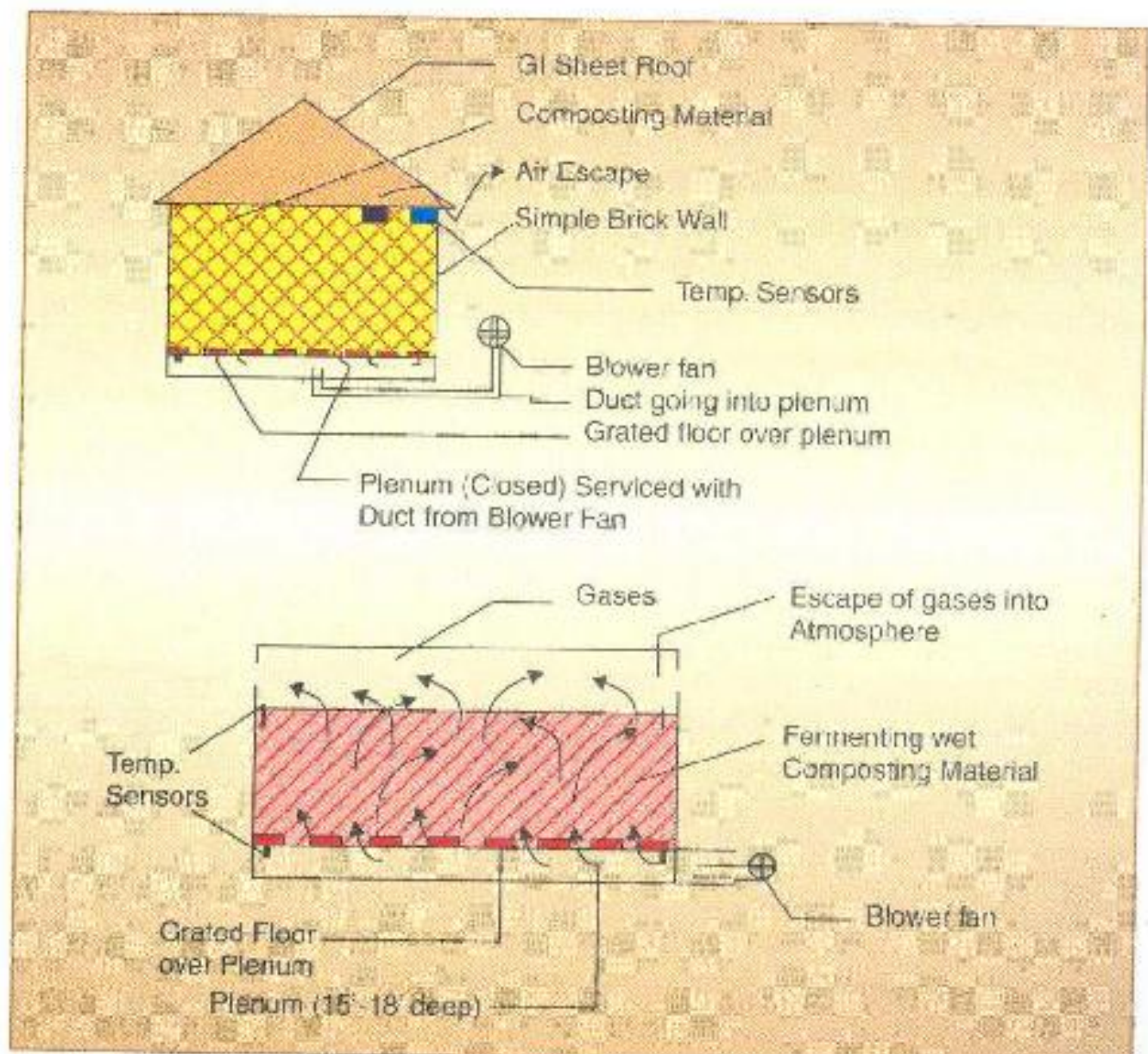


Fig. 3. Low Pressure aerated bunkers

This bunkers helps in economizing on space, is environment friendly as it emits reduced quantities of foul gases and carbon dioxide, saves labour and results in lesser shrinkage of the composting materials.

(b) High pressure system-spigot bunkers: The second type of aerated phase-I bunker is built in similar fashion as in low pressure bunkers but for the difference in aeration system laid in the floor of the bunker. The floor of this bunker contains spigot openings for air delivery into the composting material heaped over the perforated floor. The spigots are plastic cones, with wider end open with dia of about 1 ½ " -2 " and the narrow end with ½ " dia. One hole is drilled on narrow end side with dia of 6mm (+) for air delivery. The wider end of spigot is joined with the pipes in the plenum. The spigots are joined to the pipes running parallel to the longer sides of the bunker plenum, which are connected together with a U-pipe, and finally connected to the duct of a high pressure blower fan. The blower fan will have the capacity to deliver air quantity at 25 m³ /ton /hr with pressure of 700 mm water level. The spigots open in the floor surface in grooves which are 3 cm wide and 2 cm deep, placed at 40 cm apart (both groove to groove and hole to hole).

Pasteurization / phase-II of composting: The bulk pasteurization chamber and peak heating chamber are principally used for phase-II of composting for pasteurization and high temperature controlled aerobic fermentation (also called conditioning). For this purpose, an insulated chamber is built with facility for recirculation, steam inlet, blower and controlled fresh air entry. The insulated chamber is built with purpose of cutting off the external environment and stimulating a desired high temperature environment inside for controlled fermentation of the composting ingredients. Two types of chambers are used for this purpose i) peak heating chamber and (ii) bulk pasteurization chamber (tunnel).

ii) Peak heating chamber: The peak heating chamber consists of an insulated room with facility for injection of steam, air intake and air circulation. This room is built with insulation on ceiling, floor and 4 walls of the door. The shelves/trays are filled with green compost after completion of phase-I. The air circulation fan is switched on to equalize temperature in the compost beds/air. After equalization, steam is injected into the room with vents closed and temperature of the air raised to 57-58 °C and held at this temperature for 6-8 hours for pasteurization of compost. The compost temperature will be higher by 1-2 °C. This is followed by conditioning at 48-53 °C with introduction of some fresh air (about 20% of total volume of air recirculated). This lasts for 5-6 days till ammonia smell disappears. This facility is more suited when smaller amounts of compost

are handled. The modification of this system is what we term as 'single zone system' of composting. In this system all rooms on a mushroom farm are excellently insulated and provided with steam, air handling, cooling and heating facilities. The compost after phase-I is filled in racks/trays in the cropping room for all operations in a row, like pasteurization/conditioning, spawn run, case run and cropping. All the operations are done in the same chamber for labour economy and efficient utilization of the available space. This system can be more efficient in already built structures like cold storages etc. where the entire space is utilized to maximum efficiency without investing in construction of bulk chambers for composting. The single zone system is expensive and the initial capital cost is higher, as all the rooms will have to be provided with facilities for all the operations to be carried out in series. This system is in use in some of the old mushroom farms in Western Europe and most of the farms in the USA.

iii4) Bulk pasteurization chamber/tunnel: This is a modification of the peak heating chamber with the difference that in this case compost is handled in greater bulk quite efficiently (Derks, 1973, 1984). This is termed as 'double zone system'. The compost after phase-I is filled into specially built chamber which is properly insulated and provided with steam connection and air blowing system for re-circulation. The compost is filled in the chamber on top of the perforated grated floor built over the plenum. The plenum is provided with an air circulation duct used during pasteurization/conditioning (Fig.4).

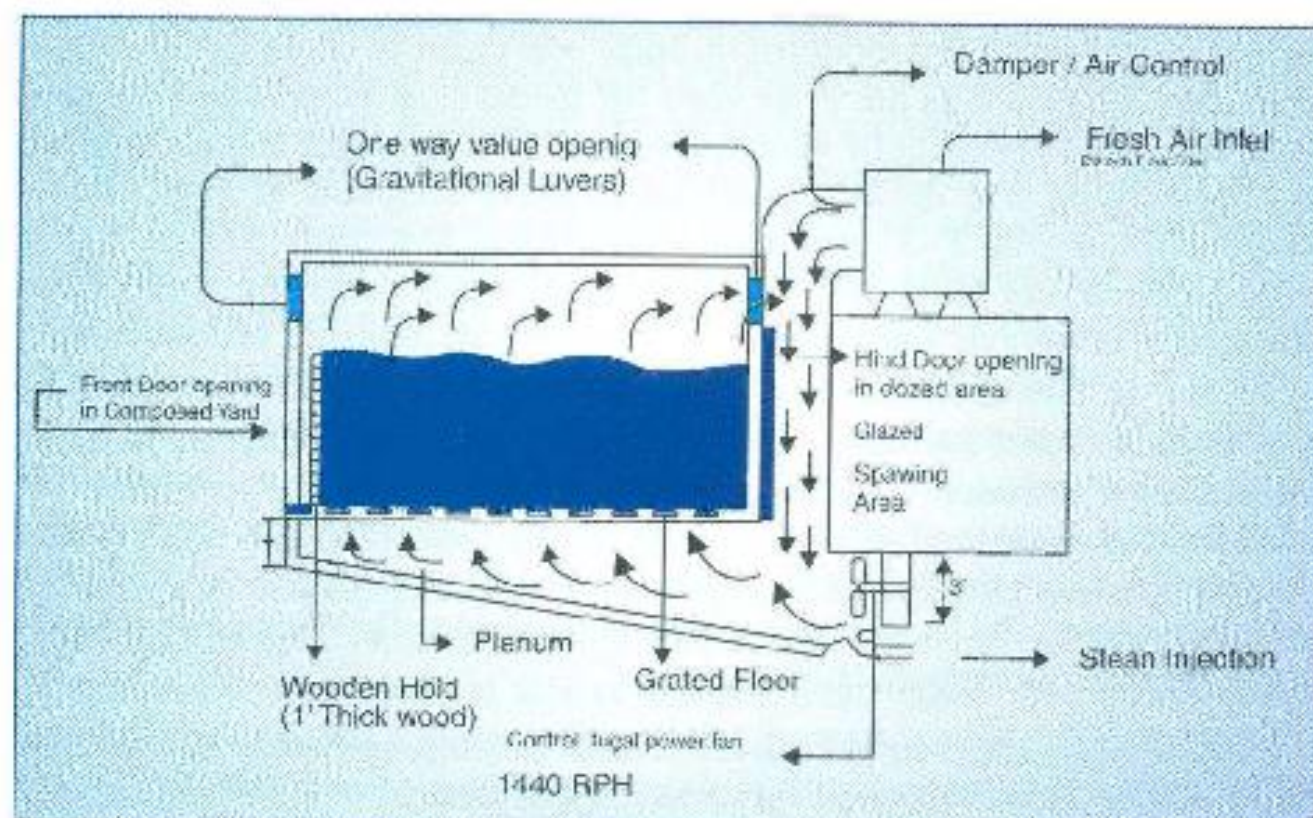


Fig. 4. Cross section of Bulk Chamber (Length 45m, Breadth 10m, Height 13m)

The bulk chamber should be constructed on distant end, (away from road) of the composting platform. One end of the bulk chamber opens into the platform and the distant end in the clean spawning area. The foundation of the bulk chamber is dug on a firm base ground. The foundation is dug 1.5 to 2 feet deep, depending upon the firmness of the ground. The floor of the chamber should be laid starting with a sand layer 15-20 cm thick, followed with a layer of broken brick/stone chips 10cm thick and a concrete floor (1:3:6); and insulation with thermocol/glass-wool 5 cm thick (15kg/m³ density). The insulation is covered with isolating membrane of PVC sheeting followed by 5 cm cement floor and finally the finish. Such floor is constructed (as above) for both cropping room and the chamber. The walls of the chamber should be 9" thick (one brick lengthwise) built over the concrete foundation. The length and breadth of the bulk chamber will vary, depending upon the amount of compost to be treated in the chamber, with the height of 13 ft. The roof is made of 4" thick RCC. The walls, ceiling and the floor below the plenum are insulated with 5 cm thick insulating material (15kg density per m³) necessary for effective insulating effect during pasteurization and conditioning of the compost (Vedder, 1978). The floor must be laid with a good run-off provided with a drain to facilitate cleaning. Air leakage in bulk chamber must be prevented at any cost. The grated floor is laid on top of the plenum over the ventilation duct. The grated floor must allow the air to pass through, for which approximately 25-30% of the floor area is left in the form of gaps for ventilation/circulation of air and steam. The plenum is divided with a perforated brick wall (one or two) in the centre for supporting the grated floor. The gratings can be made of wood (painted with bituminous paint), coated iron strips mounted on angle iron frame or of reinforced cement concrete. If nylon nets are to be used for mechanical filling and emptying, then cemented grated floor with appropriate RCC strength is built specially for the purpose. The doors of the bulk chamber are made of angle iron or wooden frame with 2"-3" insulation in the middle and covered on both sides with aluminum or GI sheets. The chamber will have two exhaust vents, one for recirculation exit and the other for exhaust of gases on introduction of fresh air via filtered dampers. Fungal filters of 2-3 μ are fitted on the entry points to keep out pathogenic fungal spores and other pests. The fresh air dampers are provided on top of the roof and connected with recirculation duct for introduction of fresh air when needed. The chamber is serviced by a blower fan below the plenum, installed in underground room or on the side of the chamber. The blower fan size will depend upon the tonnage of compost to be handled in the bulk chamber.

A centrifugal blower fan is built to order as per requirement. Air quantity of 150-200 m³/ton of compost /hr with return air pressure of 80-100 mm at entry point is required for the bulk chamber. For mechanically filled/emptied chamber, nylon mats are used which will require the return air pressure of 150 mm.

The steam line is also connected at the entry point. The walls and ceiling are damp proofed by coating bituminous paint on inside over the cemented surface, which serves as an effective vapour barrier. The grated floor inside and the work floor outside should be of the same height for operational convenience.

Two types of tunnels (bulk chambers) are in use, two door bulk chambers and single door bulk chambers. In the single door bulk chamber, the same door is used for filling and emptying and the other end is utilized for fixing installations (blower, etc.). In double door bulk chamber, one door is used for filling (which opens into the composting yard) and the other for emptying (opening into the sterile spawning area). Apart from effective insulation and damp proofing the walls/ceiling, no other specific requirements need to be met in construction of a bulk chamber. The ducting (insulated) for recirculation of air and fresh air entry is made of aluminium or GI sheet, 18" x 18" (fig 4).

The bulk chamber can be filled/emptied manually or by conveyer belts/machines. The uses of machines for filling/emptying are labour saving, time saving and ensure maintenance of absolute cleanliness during operations. For mechanical emptying two nylon nets are used, one fixed over the RCC grated floor and the other moving over the lower net (pulled by a winch). The compost when brought out is fed into the spawning machine where requisite amount of spawn is mixed with the compost and the seeded compost is then filled into clean polythene bags for transport to the growing room.

Cooling of compost in tropical areas in summer months-special requirement in compost bulk chamber: Cooling equipment installation is required for cooling of compost after completion of conditioning in summer months, when outside ambient temperatures are around 35-40°C. One air handling unit (AHU) with cooling coils is installed as part of blower system underground for cooling of compost. This additional arrangement is required only under tropical conditions where the outside ambient temperatures are higher in summer months. This system is proving very effective for cooling of the compost after completion of composting process in tropical areas.

Casing pasteurization chamber: The casing pasteurization chamber is an insulated chamber like compost pasteurization chamber with a steam connection and a blower fan for effective circulation of steam inside the chamber for attaining correct temperatures for pasteurization of the casing materials (Fig.5). The size of the chamber will depend upon the size of the compost chamber and the size of the growing rooms. One chamber load should provide casing for one compost lot from each tunnel. The casing after wetting is filled into the perforated wooden/aluminum trays which are stacked one over the other inside the chamber and steam treated at 65°C for 6-8 hours. The door of the casing pasteurization chamber should also be insulated

as in compost bulk chamber and made air tight by fixing a rubber gasket on the inner boundary of the door. This chamber should be built away from the composting yard to maintain absolute hygiene and cleanliness.

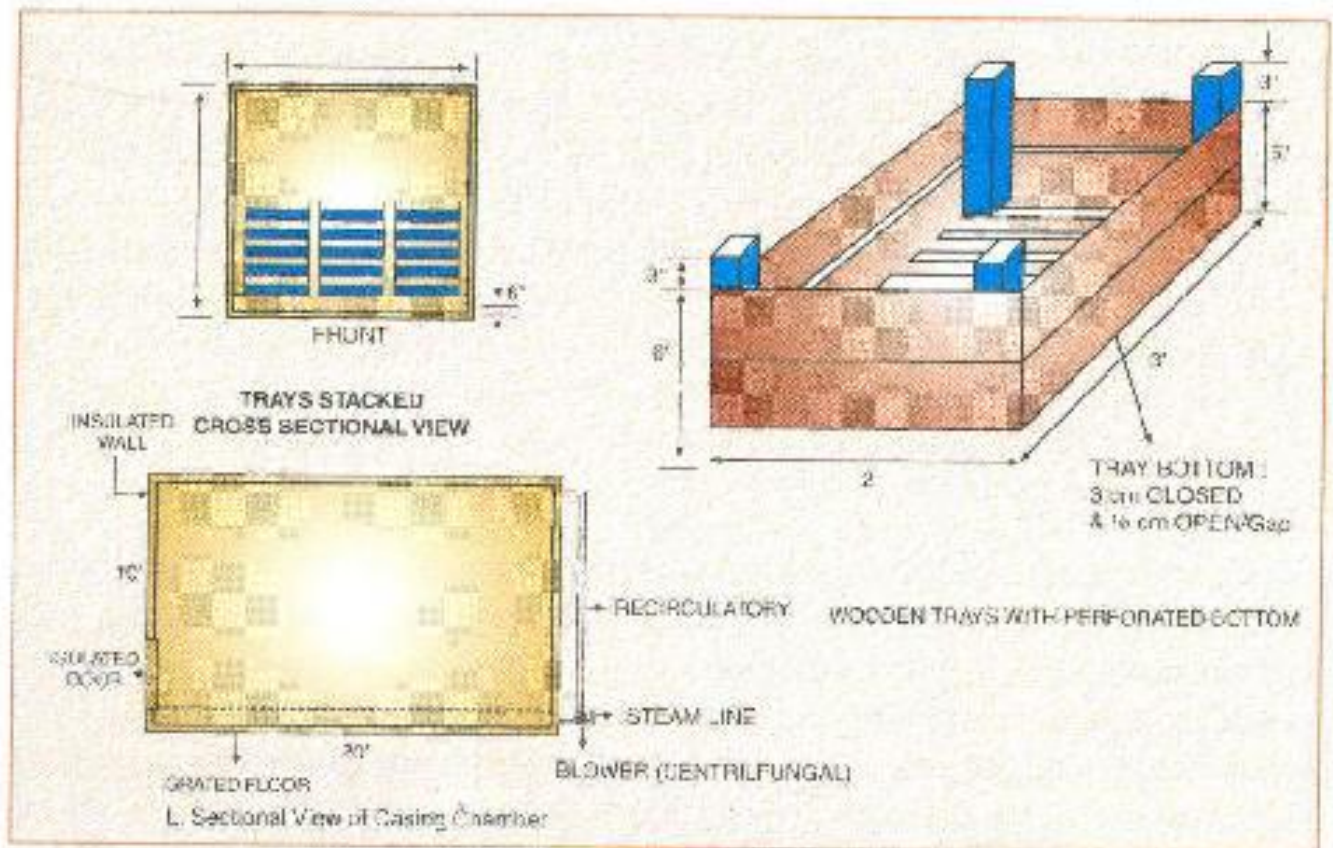


Fig. 5. Casing Pasteurization Chambers

In India tremendous problem is experienced in selection and use of casing materials as peat is not available in our country and rotten Farm Yard Manure (FYM) and Spent Mushroom Compost (both 2 years old) are used as a casing medium with fairly good results. But there is problem of salt accumulation in these materials, resulting in higher electrical conductivity. This can be rectified by washing/steeping these materials in clean water for 4-6 hours before steam pasteurization. So, construction of cemented water channels/tanks with arrangement for free flow of clean water above and drainage below will be required to wash/steep the casing material before use. Decomposed Coir Pith is also recommended to be used as casing material with good results.

SPAWN UNIT

Mushroom mycelium grown in pure culture on some nutrient base and used for seeding of the substrate for mushroom growing is technically called spawn. For cultivation/domestication of edible fleshy fungi, it is necessary to bring the mushroom fungus into pure culture and multiply the fungus on some medium like Malt Extract Agar medium and then prepare its spawn on wheat grain for seeding of the substrate. Spawn preparation is thus the first step in the cultivation of mushrooms. The spawn production involves

three major steps, i.e. raising of pure culture of the fungus and its maintenance, preparation of mother inoculum/mother spawn and multiplication of planting or commercial spawn from mother spawn.

Layout plan of a spawn laboratory

A minimum built area of 60'x30'x14'(h) is required for a moderate sized spawn laboratory capable of producing about 50 tons of spawn per annum (Dhar, 2002). The capacity of spawn production laboratory can be increased by adding more incubation rooms to the unit (fig.6). A bigger laboratory of 100'x40'x12'(h) size will have the capacity to produce more than 100 tons of spawn per annum (fig 6).

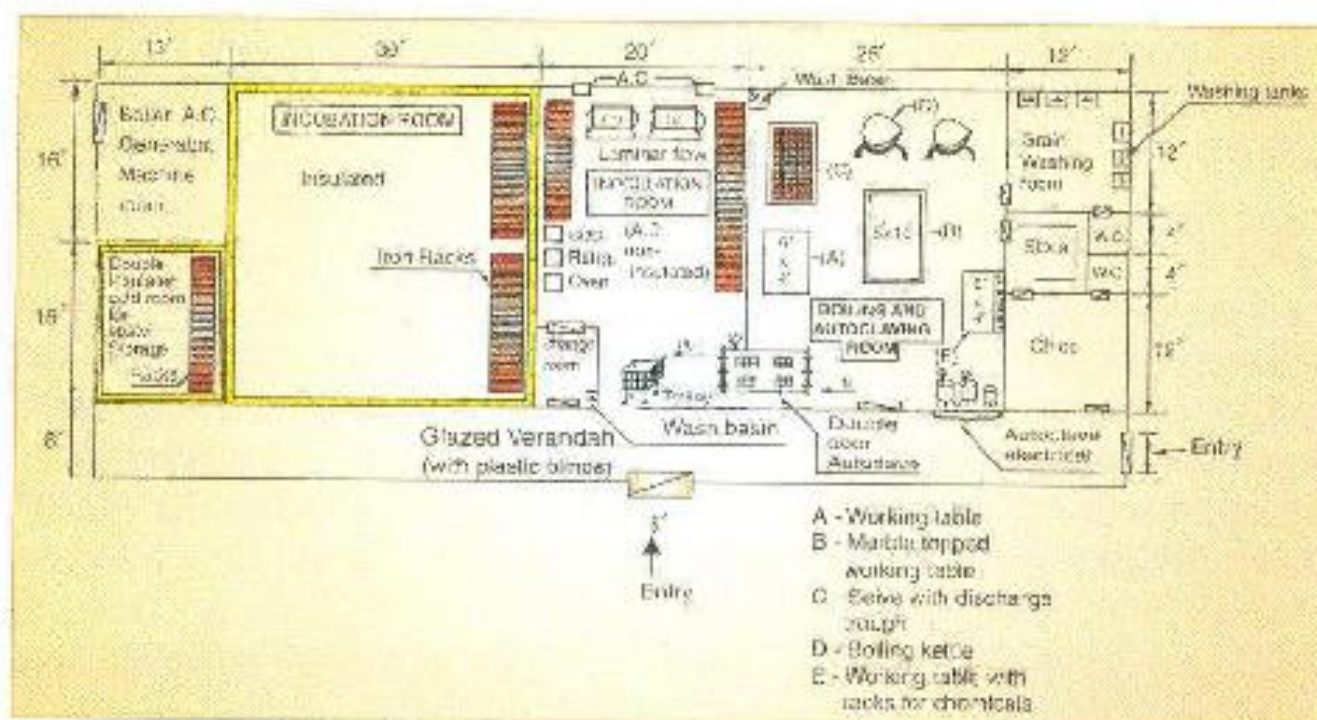


Fig. 6. lay out plan of a spawn lab

The spawn laboratory requires various sections/rooms for various operations in a series. One is a washing room where grain is washed in water tanks serially. The second room is required for cooking/autoclaving, where grain is boiled, surface dried and poured inside the glass bottles/pp pages (after mixing of calcium carbonate/gypsum) for autoclaving/sterilization. The third room of a spawn unit is used for inoculation under sterile condition on a laminar flow. The 4th section is the incubation room where the inoculated spawn bottles/bags are kept in an insulated incubation room with arrangement for heating / cooling at required temperature for a particular type of mushroom. The fifth room of the unit is a well insulated cold storage with a cooling system for maintenance of temperature at 2-4°C for spawn storage. The additional space required will be in the form of a store, office, A/C equipment room and general space (covered verandah) for equipments like BOD incubator, refrigerator, pH meter, oven and such other equipments required in a spawn laboratory. The

spawn laboratory should have clean water connection with proper drainage and provision for uninterrupted power supply. The spawn unit should be located away from polluted area and main road, and preferably have a green surrounding for keeping the dust away. The spawn laboratory should have a motorable approach road for transport of raw materials to the unit and finished product from the laboratory to the user.

The layout plan as shown in figure 6 is a generalized one, and various rooms marked for different operations can be relocated in the building as per convenience of operations and availability of space.

Materials / Equipments required : Grain washing tanks, boiling kettle-steam jacketed, autoclave, working tables-SS top, laminar flow, iron / aluminum racks, air conditioners, hot air blowers, BOD incubator, refrigerator, pH meter, weighing balance, glassware, plastic ware, pp bags, glass bottles, double distilled glass apparatus, non absorbent cotton, others.

CROPPING UNIT

Since mushrooms are grown indoors under simulated environment specially created for a particular mushroom, the cropping rooms are required to be specially built for the purpose. Two types of cropping rooms are used for crop raising suiting a particular requirement – cropping rooms required for seasonal growing with no environment controls and those for environment controlled growing all the year round (Fig. 7).

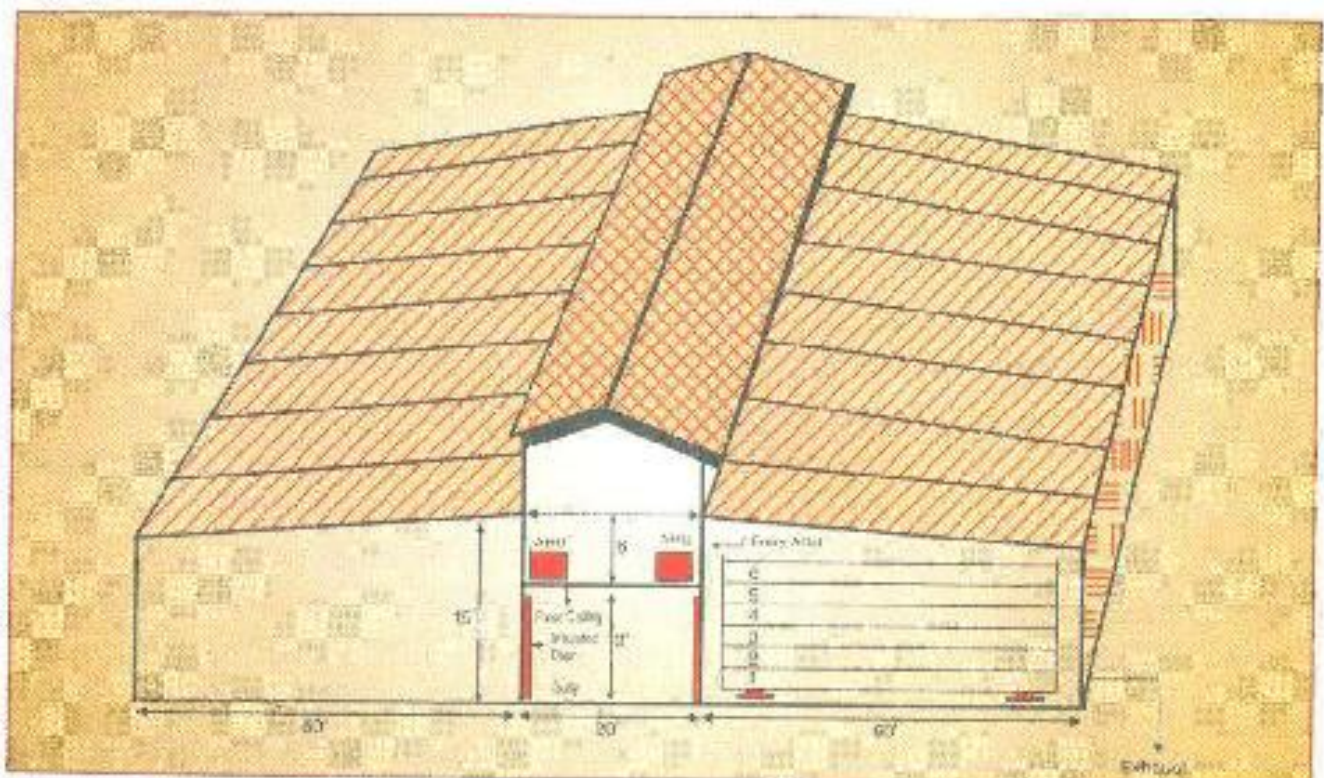


Fig. 7. Front cross Sectional View of Cropping Rooms

Seasonal cropping rooms: Seasonal cropping rooms are simple rooms with modifications made for maintaining various growth parameters. These cropping rooms will have a cemented floor, cemented walls, cemented ceiling or a false ceiling with arrangement for forced air circulation duct inside. The seasonal cropping rooms are built of simple brick walls with roof made of asbestos sheets and a false ceiling. The room is more or less made air tight to make the forced air circulation system work effectively for obtaining necessary air changes during growing. No insulation is required for seasonal growing rooms as it will not allow heat dissipation from the room efficiently. These simple rooms are used for seasonal mushroom growing, coinciding various phases of crop growth with prevailing outside temperatures. No energy is used for heating/cooling of the rooms under seasonal growing conditions. The cropping rooms for seasonal growing can also be made with a thatched roof and a false polythene ceiling. The door is installed on one end and the exhaust vents on the opposite end of the door. The forced air circulation fan is installed on top of the door (Fig.8). The mushrooms are grown on beds made out of bamboo and sarkanda stems (a plant abundantly growing as a weed in North Western plains of India). These growing rooms can also be built as low cost structures, steel pipe frame with high density polythene covering from outside. The real low cost-low technology growing houses built in rural areas are made from bamboo, paddy straw and sarkanda, with walls, roof and door made of sarkanda stems. The air is exchanged in this room through porous walls all the time. But these houses are totally at the mercy of the climate and low winter temperatures interfere in the normal crop production.

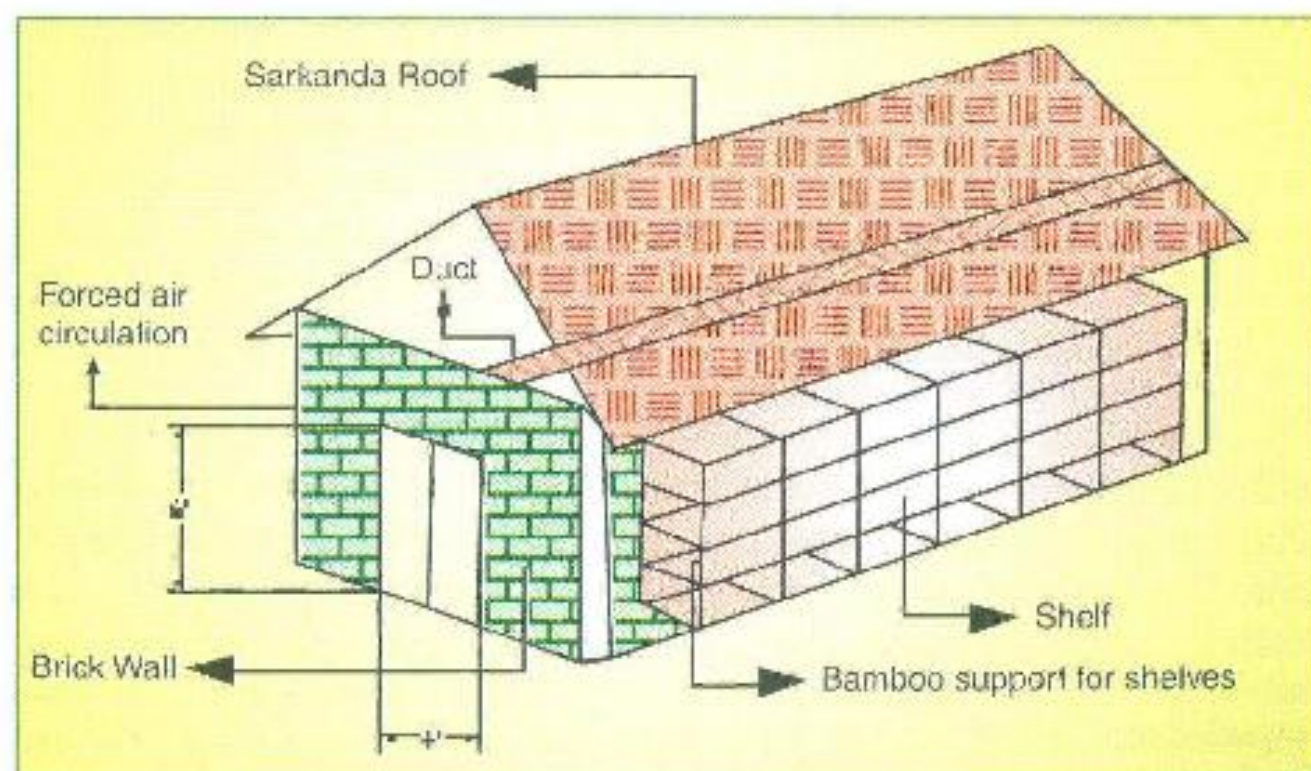


Fig. 8. Low cost growing room

The mushroom houses made with bamboo frame and synthetic fiber cloth material, both inside and outside, with paddy straw insulation inbetween has also given good results under hill conditions for seasonal growing (details given separately under low cost structures).

Environment controlled cropping rooms: The environment controlled cropping rooms are built like hermetically sealed insulated chambers where the air movement is controlled either manually or semi automatically with mechanical control systems. These cropping rooms are appropriately insulated and the dimensions of a cropping room are determined by the amount of compost to be filled into the room. Rooms with greater length and narrower width give better results as far as air handling inside the room is concerned. A cropping room with a capacity to take compost from one bulk chamber is considered advantageous as one bulk chamber load can straightaway be filled into one cropping room. Both bulk chamber and cropping rooms of 20-25 tons compost capacity each are considered to be operationally efficient, as the operation of filling/emptying and spawning of 20-25 tons of compost can conveniently be done in one day manually, when machines are not to be used. For this quantity of compost, cropping room with the following dimensions are in use in various parts of the world.

- i) 55' x 18' x 12'
- ii) 60' x 22' x 12'
- iii) 35' x 25' x 13'
- iv) 60' x 22' x 10' (low cost structures)
- v) 40' x 20' x 13'

The cropping rooms with above dimensions are used with shelves in 5-6 tiers inside (3-5 shelves), each room holding 20-25 tons of compost, the variation being adjusted more with varying the depth of compost layer. Polythene bags are also used for growing mushrooms in these growing houses, with approximately similar capacity of compost holding (Fig.9).

The foundation of growing rooms should be laid on dry and firm ground. The floor is laid as explained for bulk chamber. The walls will be made of one brick thickness (9" thickness) and ceiling made of 4" thick RCC. The growing rooms will have a single insulated door and 2 vents for exhaust on the back wall at ground level. One opening is provided on top of the door for entry of duct of the Air Handling Unit (AHU). The walls, ceiling and floor are insulated with 5 cm thick insulating material. The rooms are made air tight and all leaks sealed to prevent ingress of heat from outside. The cooling, heating and forced air circulation in the growing room is done with use of air handling unit (AHU) installed outside the room for each cropping room individually. The floor and walls of the cropping rooms should have a smooth finish with floor given a gentle slope towards the discharge drain/ trap in the room.

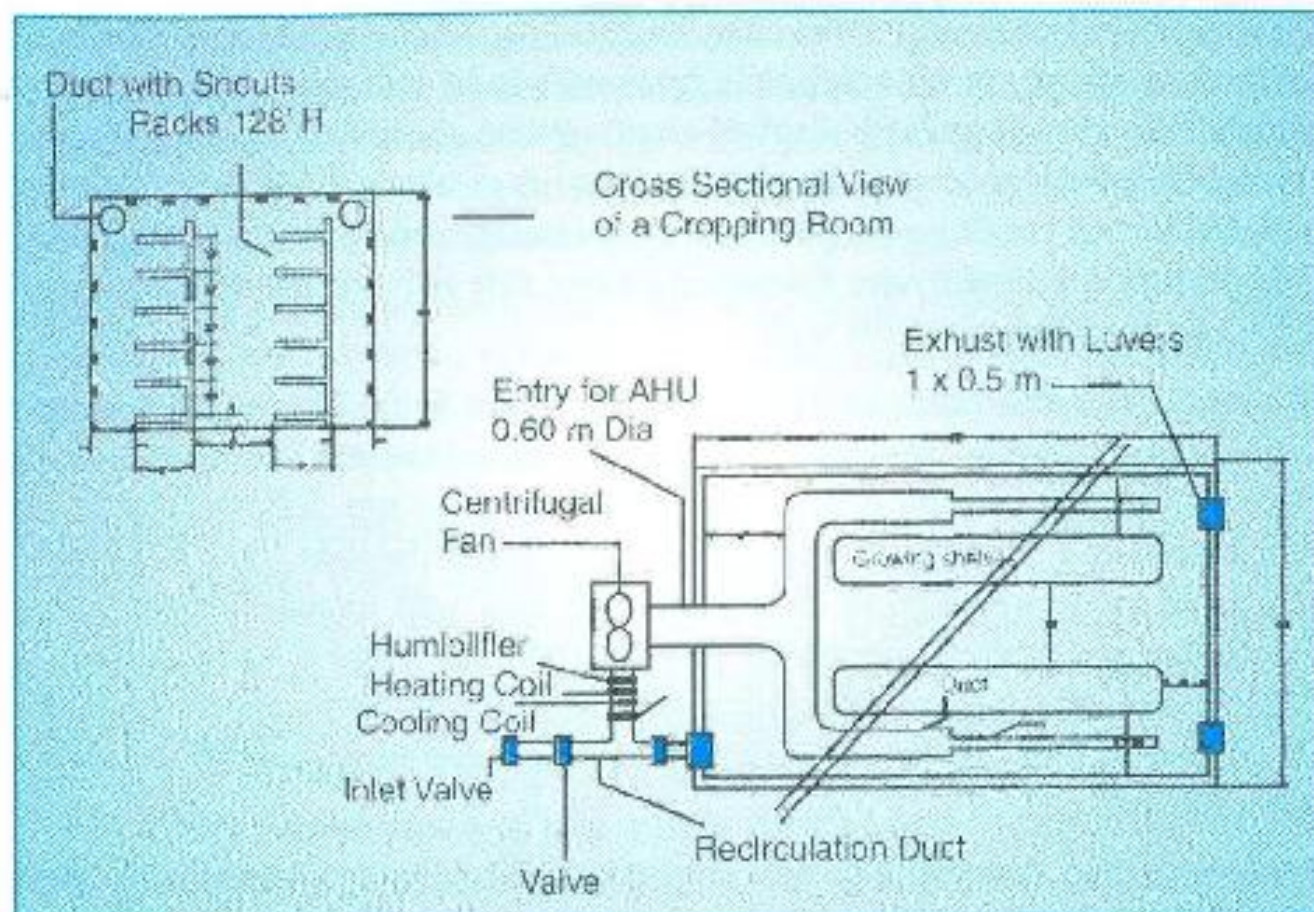


Fig. 9. Internal Layout of a Cropping Room 60' x 22' x 13' / Two rows and six tiers

Structural details special to cropping rooms

Floor: The floor must be well laid out and should be strong enough to take the heavy load of multi tier metal racks to be installed inside for growing mushrooms. After digging start with a bed of sand 15-20 cm thick, followed by 5 cm thick concrete floor (1:3:6). The floor should then be insulated with insulating material 5 cm thick (compressed sheet of thermocol/glass wool/polyurethane). The insulation should be protected by a PVC sheering, below and above, against moisture. It is then covered with wire mesh and finally 5 cm thick concrete floor is laid on top, which is given a smooth finish. The floor should be given slight slope towards the discharge drain/trap for discharge of cleaning water. The drain/trap in the cropping room is connected to main drain in the corridor to discharge washings from the room. The water discharge hole of the cropping room is protected at this point to prevent leakage of air from the growing room.

Walls: The walls are made of bricks (22.5 cm thick), which are given a smooth finish with cement plaster. The insulation sheets are fixed on the walls (5 cm thick thermocol/glass wool/polyurethane), with the use of hot coal tar. Holes are drilled on four corners of the sheet/inside the cement wall (for expansion fasteners) which are fixed by screwing in the nail with 4"-5" long steel wire tied on its head. The wires hanging out of the sheet are

later used for tightening of wire net fixed on top of the insulation. The layer of cement plaster is then applied (2cm) on top of this and given a smooth finish. Bituminous paint is applied over cement plaster as a vapour barrier. This wall will be good enough to give a k-value of about 0.5 kcal/m²/h, even lesser and will facilitate proper control of climate inside the cropping room. The common wall will have insulation on one side only, or one inch insulation applied on each face of the wall.

Roofs: The roof is made of RCC (1:2:4) 12-15cm thick. The inside is given a cement plaster finish for application of insulation (as explained for the wall). The roof on the outside is protected by tarring it on top, followed by 10 cm thick loose soil, 5 cm thick mud capping and finally the tiles. This will protect the roof from weathering effects of rain and will ensure longer life of insulation and prevent seepage of moisture into the room in rainy season. In hilly areas with a high rainfall index, slanting GI sheet roof over the insulated RCC roof will be excellent and in that case mud capping/tiling of the roof is not required.

Doors/vents: The doors of the cropping room (including bulk pasteurization chamber) are made of wood or angle iron frame covered on inside and outside with aluminum sheets/GI sheets with insulation of 5-7 cm in the middle. The doors will have a rubber gasket lined on inner periphery so that the door becomes air tight when closed. The door will operate on hinges, with a strong locking latch for opening and closing of the door.

The exhaust vents are normally made on the opposite end of the room entry point, on the lower part of the wall at ground level. The exhaust vents are fitted with wire net, gravitational louver and insulated lids. The louver allow the CO₂ laden air to exhaust under positive pressure created by the blower fan inside the air handling unit.

Lighting arrangement: There should be provision for tube lights and a mobile strong light for inspection in each cropping room. The tube lights should be protected with a water proof housing. The tube lights should be fitted on all the walls vertically at various heights to facilitate lighting of all tiers/beds. There should be provision for a few electric points (5 and 15 Amp.) for operation of water spraying equipment and CO₂ measuring instruments.

Water connection and sewers: One clean water pipe line (1" or 1.25") for delivering clean water for spraying should be provided in each room. Provision for underground discharge drainage line for-carrying the washings from the room and wash basin discharge should be laid before construction of the building in the corridor/rooms. This waste water line should be connected to the common sewer outside. In H.D. polythene cropping rooms, sunken

traps on the floor for fresh water connection and discharge water are provided inside the growing house with each trap of 1'x1'x1' dimension fitted with an iron lid on top. It is desirable to lay underground drainage in the central gallery in advance of erecting the structure for carrying away the waste water/ washings from the cropping rooms.

Gallery: The gallery between the rows of cropping rooms should be wide, (approximately 20 feet) to facilitate performing various operations without hinderance. The height of the gallery should be about 8' with a false ceiling, leaving another 5 feet above for pipe line and space for AHU's.

Requirement of environment control and forced air circulation in the cropping rooms: White button mushroom *Agaricus bisporus* requires 24°C for vegetative growth (spawn run) and 15-17°C for reproductive growth (mushroom production). The temperature requirement of temperature tolerant white button mushroom *A. Bitorquis* is 4-6°C higher for both the stages (28-30°C for spawn run, 22-26°C for mushroom growth). The requirement of RH during spawn run and case run is 90-95% and during cropping 80-85%. The third factor is fresh air requirement and removal of CO₂ + heat from the cropping room. During spawn run there is very little requirement of fresh air and higher concentration of CO₂ in the growing room is desirable for quick spawn run. During cropping fresh air requirement is tremendous and CO₂ has to be exhausted regularly. The CO₂ concentration during cropping, in general, should not be above 800-1000 ppm and this is adjusted as per the requirement of the strain of mushroom under cultivation. The amount of heat produced during spawn run during the first two flushes in the cropping room containing 20-25 tons of compost is about 4000-5000 kcal per hour, which has to be removed regularly by frequent air changes during spawn run. Air changes, cooling/heating, RH maintenance, heat/CO₂ removal and evaporation from the beds is constantly maneuvered inside the cropping room for getting a healthy crop of mushrooms. These factors are part of the environmental crop management and are as vital and important as quality of compost and spawn in mushroom growing. All the above factors have to be maintained in co-ordinated manner, as change in one factor affects the other. The enthalpy-lines (Moliar diagram) available for a particular place becomes a guiding factor for environment/climate creation inside the cropping room (Griensven, 1988).

Environmental requirements for seasonal growing: For seasonal growing, all the above requirements are met with by coinciding various stages of crop growth with prevailing seasonal temperatures outside. In hilly areas the mushrooms are grown seasonally all the year round with minor adjustments, raising 2-3 crops in a year. But for round the year cultivation in hills with greater productivity, environment control is essential to provide uniform

climate inside the cropping room for greater productivity in hot and cold periods of the season. The seasonal crop can also be raised in plains close to hills in winter months (October – February) with good profits. The hotter/tropical/sub tropical areas will require air conditioning and environment control all the year round since the temperatures in these regions range between 28-40°C most of the year.

Forced air circulation: Forced air circulation is very essential for introduction of oxygen and exhausting the CO₂ laden air during cropping, as the compost is microbiologically active and produces CO₂ all the time with consumption of oxygen. In controlled growing houses the forced air circulation is achieved by the use of an AHU which cools/heats, maintains RH, forces-in fresh air and exhausts the CO₂ laden air via back vents under positive pressure. Provision for forced air circulation can be made in seasonal growing houses by installing an exhaust fan on top of the door facing inwards and joined to a perforated polythene duct running along the entire length of the room. The walls and false ceiling should be air tight to make the forced air circulation system effective and workable. In low cost growing houses where thatched roof is used, polythene false ceiling will be essential to create the sealing effect on top. The seasonal growing houses should not be insulated, as it will be difficult to maintain the right environment inside the room in the season congenial for crop growth. In extreme cold areas where lower temperatures are prevalent in some part of the season, brick walls with air gaps should be good enough to prevent condensation of water on the walls in the cropping rooms.

Method of environment control: The growing parameters like temperature, RH, CO₂ and introduction of fresh air responsible for the production of healthy crop of mushrooms, need to be simulated inside the cropping room in those areas where outside temperatures are not congenial for mushroom growth. The basic requirement for air conditioning/environment control in a growing house is the insulation of the cropping room to completely cut-off the external environment from the inside environment. The air entry is restricted and controlled as per the requirement of the cropping room with use of an "Air Handling Unit" (AHU). The AHU contains the cooling coils, the heating coils and one chamber for humidification, with a centrifugal blower fan in front to pull through the air into the room for circulation via air ducts placed in the room as per plan. The recommended air pressure of the blower fan of AHU should support 50 mm of water level at the entry point. The cooling coils are supplied with chilled water at 5-6°C from a chiller in the A/C room. The number of cooling coils to be used in AHU will be determined by compost load of the room and prevailing outside temperature and is always calculated for the maximum requirement during the hottest period. The air after its passage through the cooling coils is cooled to about

13-14°C before it is blown into mist chamber for humidification. The air in the humidity chamber is brought to 100% RH at 13-14°C, and then blown into the ducts for circulation into the cropping room. By the time it reaches the crop bed, the temperature rises to about 16-17°C lowering the RH automatically to 85%. The air speed on the beds should not exceed 15cm per second, unless the air is amply humidified. The slow movement of air over the crop bed ensures slow evaporation of moisture from the crop beds resulting in removal of CO_2 + heat from the crop bed. The CO_2 gets mixed with the air and is finally blown out via the exhaust vents. This is the technique used during cropping for maintenance of required climate inside the cropping room. The requirement of fresh air is adjusted to 30% outside fresh air during first and second flush of the crop, 20% in the subsequent flushes. The rest of the air is recirculated from inside via recirculation duct connected to AHU. The fresh air/recirculated air quantities are mixed/controlled by adjustment of dampers at fresh and recirculated air entry points. The size of the damper is known and by measuring the air speed at entry point, the air quantity can be adjusted. The air displacement capacity of AHU in a cropping room should be about 4500-5000 m^3/hour for a cropping room with 20-25 tons of compost.

In temperate/cooler areas, the air can be forced in without pretreatment for cooling. In hotter regions cooling is required and for this the water is chilled (for use in AHU) in the chiller (shell/tank) in the A/C room. The heat ultimately is lost into the atmosphere via cooling tower erected on top of the A/C room. For mushroom growing rooms cooling is done indirectly by use of chilled water in the cooling coils in AHU. Alternatively, the air can be preconditioned in A/C room/air washers and then blown into all the cropping rooms, but this has a disadvantage that all rooms will have to be at one stage of cropping. Individual AHU's for each room will facilitate the use of different temperature ranges required at different stages of crop growth. The use of room air conditioners is not recommended for mushroom growing, as these will dry the cropping beds before it starts cooling.

For heating of rooms, the heating coils in AHU are supplied with steam from a low pressure boiler and number of heating coils required will depend upon the prevailing outside temperature. The RH is created in the mist chamber of AHU with the help of foggers located in the RH chamber for misting. The water is pumped into these jets with force and collected back in the trough below the chamber for recirculation. The ducting in the cropping rooms is done with precise measurements, keeping in view the number of shelves in the room and the total bed area, with amount of compost.

The duct should be laid in such a way to ensure slow movement of air over the crop bed surface. This can be checked by burning incense sticks

paddy straw in between two walls of synthetic cloth helps in maintaining temperature of 5-6 °C higher than in ordinary seasonal mushroom growing rooms in winter months.

The construction of this low cost insulated cloth hut is done in similar fashion as explained for bamboo hut. The floor is laid with broken stone/broken brick 6-8" thick, followed by 6"-8" of sand. The bricks are fixed in the sand and in this way the brick floor is made smooth and properly leveled. The plastic / iron pipes 3" in dia and 18" long are grouted at 3'-4' distance all along the periphery in double row (1 feet apart). The bamboo poles are fixed in these holes and structure erected as in bamboo hut. But in this case two rows are created. The bamboo poles of 8 feet length are fixed in these pipes and basic structure built of bamboo (double walled with gap of 1 feet). The slanting roof with inner polythene layer + outer sarkanda layer is laid on top as a roof (water proof). The synthetic cloth is fixed on inside of inner bamboo poles and outer layer on outside of outer bamboo poles in a row. The gap in between is packed with paddy straw, and the wall area sealed with synthetic cloth on top as well. The bamboo shelves are built as in split bamboo house. The door is also built of double bamboo structure with synthetic cloth on inner and outer side (figure 12). Two vents (16" x 16") , one in front and one at the rear are provided for air exchange/ aeration. A drain is dug on the outer periphery to carry away rain water.

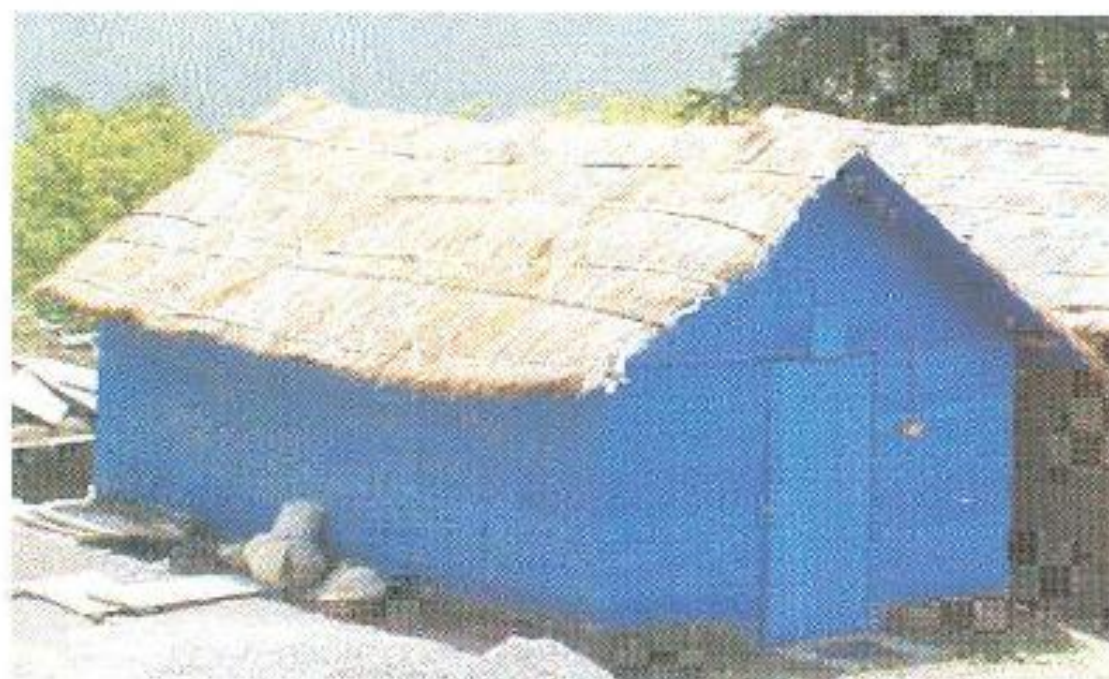


Fig. 12. Bamboo- paddy straw insulated poly house

(iii) Bamboo Huts in North Eastern Hills (a modification)

In Megalaya, the mushroom houses are constructed using locally available materials like bamboo, thatch and mud plaster. Walls are made up of split bamboo plastered evenly inside with a mixture of mud and cow dung. In order to insulate

the inside environment, a second wall is built all around the house, keeping about 15cms space between the first wall and the second. Mud plastering is done on the outside of the outside wall. The air space in between the two walls acts as an insulator. The floor of the house is made of mud or bricks. A false ceiling is built to keep out the contaminants from the thatch roof. Besides the front door, ventilators are provided in the upper and lower positions of the front and rear side of the room for proper exchange of air inside the room. The front view of the mushroom house is shown in Fig.13.



Fig.13. Front view of low cost mushroom house in Meghalaya

CANNING UNIT

Layout of a canning unit

A general layout of a canning unit of about 1-2 tons canning capacity per day is given in line drawing as under. However, minor modifications can be done for placement of equipments suiting the space availability. Canning unit / processing unit should not be less 100 m² built area with 14' height as per FPO specification. Before establishing a commercial canning unit, it is necessary to consider certain important factors such as investment, site, building, water supply, labour etc., in addition to FPO license from the Ministry of Food Processing Industry.

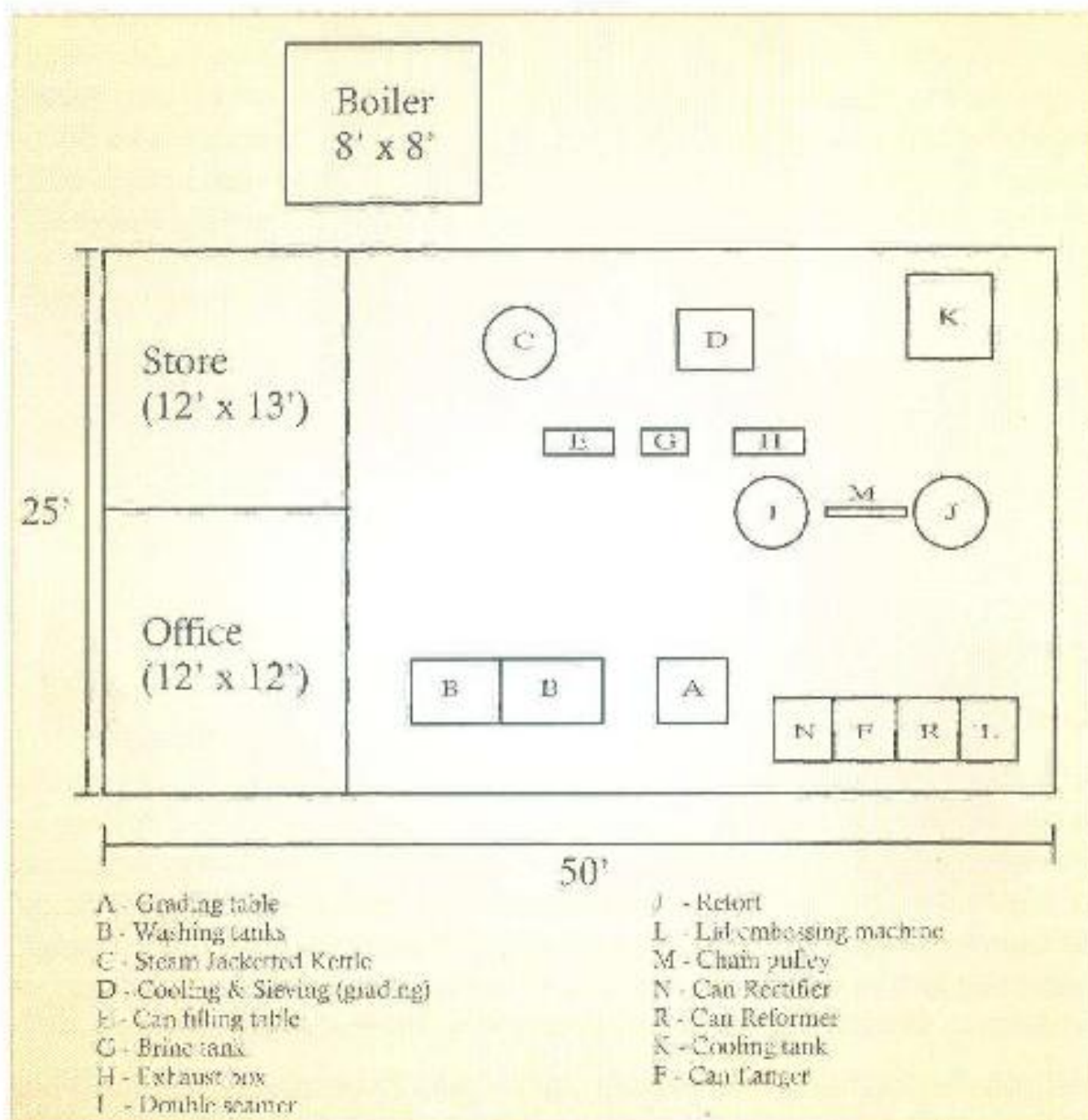
The capital out-lay for canning unit includes investment on land, building and machinery. The running or operational expenses include the cost of raw material, labour, processing, storage, transport and marketing

Location

The unit is built as an integral part of large mushroom farm and can also be established as an independent food processing unit. The site should have access by a motorable road for proper transport facility, with clean environment and arrangement for sewage disposal. The site should be away from smoking chimneys and other hazard discharging factories which could effect the quality of canned product. The site should have abundant water supply available with facility for electric power supply (3 phase).

Building of canning unit

A general layout of a canning hall with placement of various equipments in series for canning of 1-2 tons of mushroom per day is given



in Figure. 14. Floor of the canning hall should have good slope @ 1/4 inch per feet running length towards the discharge drain for discharge of washings from the canning hall. All doors, windows and ventilators should be provided with fine wire mesh to prevent flies and insects entering the unit. The entry door should have double door system for prevention of insects into the hall.

Button mushrooms are highly perishable with very short shelf life of few hours to a day, depending upon the outside ambient temperature.

Among the various preservation methods followed, canning is the most commonly used method universally. The process of sealing processed foodstuffs in hermetically sealed containers and sterilizing these by heat for long term storage is called canning(Azad et.al., 1986). Canning method is the most popular method of preserving mushrooms for longer storage. Many Asian countries like India, China, Taiwan, Korea, Indonesia export their produce to the American and European countries in the form of canned mushrooms. The machineries involved in the canning of mushrooms with description of each functioning unit is described below in the order it is used in the canning line :

a) Lid-Embossing machine

This machine (Fig.15) is used to emboss the lids with the required reference letters or figures like date of manufacture, date of expiry , rate and quantity etc.,. This machine is operated by a foot paddle which, when pressed, embosses the lid by virtue of marker dies, without piercing it.

b) Can-reformer

This is simple machine (Fig.16) which reforms the flattened can bodies to round shape, prior to flanging. The flattened can is mounted on to the rubber roller and on pressing the pedal, it presses the can against the rotating steel roller thereby giving it a round shape.





c) Can-flanger

This simple hand operated machine, (Fig. 17), is used for simultaneous flanging of both sides of the round can after the operation of the can-reformer. A toggle motion balanced hand-lever enables the machine to be operated with minimum exertion. The flanging is necessary to enable the bottom/top lids to be fixed in the can with leak proof sealing.

d) Flange-rectifier

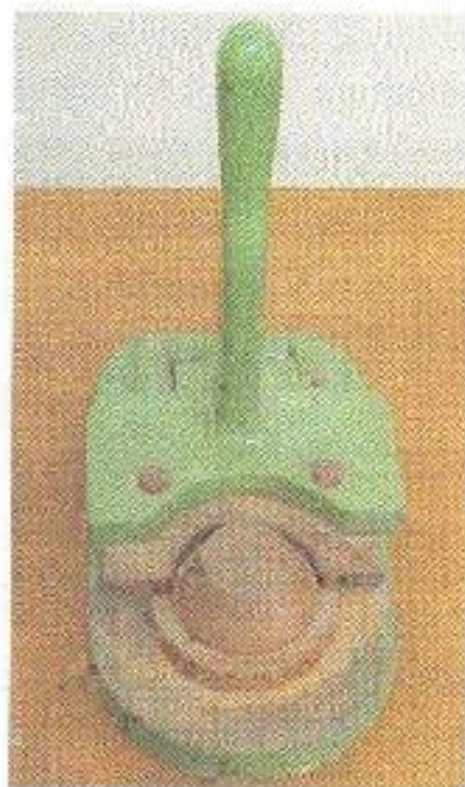
This is a simple hand operated machine (Fig.18) used for rectification of misshaped flanges of cans. The misshaped flanged can is placed on the die and by simple application of the handle, the flange is rectified.

e) Double-seamer

This is a semi-automatic machine (Fig.19), most suitable for seaming processed cans as well as flanged cans with the embossed lids on both sides.

f) Double jacketed kettle for blanching of mushrooms

This kettle/vessel (Fig. 20) is mounted on a heavy duty mild steel stand with tilting





arrangement. The kettle has a double jacket at the bottom end for maximum steam utilization and efficiency. Both the pan and jacket are made up of high quality stainless steel. This is mainly used for batch heating and blanching of mushrooms.

g) Exhaust box

This machine - a moving conveyer belt enclosed in a steam heated long box (Fig.21), consists of a chain conveyor base moving at low speed to allow the cans filled with mushrooms be in contact with steam for 1 to 2 minutes, to bring the contents of the can to boiling condition by the time it reaches the end of the box (exit point).



h) Canning retort

This pressurized vessel /equipment (Fig.22) is used for sterilization of sealed canned material under pressure, after operations of filling and seaming are completed. It is equipped with pressure gauge and safety valve. The mushroom cans are sterilized at 15 psi for 45 minutes to sterilize the contents for longer storage/to prevent spoilage during storage.



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